ΟΡΓΑΝΙΣΜΟΣ ΒΙΟΜΗΧΑΝΙΚΗΣ ΙΔΙΟΚΤΗΣΙΑΣ

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γ) την αίτηση που κατέθεσε ο ενδιαφερόμενος στον Ο.Β.Ι. στις **20-03-2000** με αριθμό **20000100089**.

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Αθήνα 30 Αυγούστου 2001

Ο Γενικός Διευθυντής

ΕΜΜΑΝΟΥΗΛ ΣΑΜΟΥΗΛΙΔΗΣ

Dual band dipole antenna array with corner reflector

This invention is relevant to corner reflector antenna arrays which are used in wireless telecommunication base stations, like the case of mobile telephony. In particular, it concerns an antenna array which can simultaneously resonate in two frequency bands, preserving in both two bands the same excellent electromagnetic radiation characteristics that are demanded accordingly to any case.

The antenna arrays are geometrical arrangements consisting of specific geometry elements which transmit electromagnetic radiation in free space and are usually used by broadcast base stations and mobile telephony base stations as well. The reason, why the antenna array is preferable to a single element in a base station, is that a properly designed array can radiate in space in a specific way, that is to give a radiation pattern corresponding to a user's demands. These demands are usually: (a) to get the possibly maximum power gain from the antenna array, (b) to receive radiation at satisfactory levels, through a main lobe of the transmitted radiation that has a definite half power angular beam-width, only from receivers located within this angular beam-width and (c) to have a secondary lobe level of radiation pattern that is sufficiently lower than the main lobe level. In addition, the antenna array must be in resonance condition throughout the entire operation frequency band, which means that the antenna impedance must be as close as possible to the value of characteristic impedance of the transmission line which feeds the antenna array, so as to minimize the power reflection effect on the transmission line and consequently the standing wave creation.

However, a problem that appears is that the above demands can be satisfied by the antenna array in a certain frequency, or better, in a certain frequency band. This occurs because the lengths and the distances of the elements that compose the whole structure of the array have values that depend on the emitted radiation wavelength. Thus, we cannot ask that the array equally satisfy all the above demands in any other frequency band different from the previous one, since the relation between the lengths and the distances of the elements that compose the array and the newly given frequency band wavelength is different. For instance, a mobile telephony base station array, designed according to the above demands to operate on the frequency band of 900MHz, cannot be used to operate on the band of 1800MHz. In this second frequency, the wavelength gets half the value in relation to the respective wavelength of 900MHz, resulting in lengths and distances of the elements that compose the whole array structure, having double the value in relation to the wavelength of 1800MHz. The radiation characteristics will dramatically become worse and of course, the antenna array will not be in resonance condition, resulting in the generation of a strong reflection effect. Due to this effect, a significant percentage of power will be going back to the transmitter instead of being radiated, resulting in increased power loss.

The only solution that has been proposed so far, aiming the operation on two different frequencies, is the use of a single element instead of an array. It must be pointed out that, in the case of the array, the distances among elements determine the coupling among them. This coupling may be constructive in one frequency and help the array to satisfy the above demands but may be baneful in another frequency. However, when we use one and only element there is no matter of coupling, so the designing is simpler and easier. Nevertheless, in this case, though there is the disadvantage of low gain and low radiated power, not all of the demands will be satisfied.

It must be mentioned that in the past some arrays that have been recommended operate in resonance in two different frequencies, with the difference that the array elements are small metallic surface pieces covering a thin dielectric layer. It concerns the familiar microstrip antennas, whose manufacturing is made by the known technology of printed circuits. The disadvantage that arises in this type of arrays comes from the element structure used where high power must not be radiated, because the elements will be destroyed.

The present invention means to satisfy every above-presented demand in two frequency bands at once, as well as to negate disadvantages being presented by structures of the same technical area with the one of the invention.

According to the invention, the antenna array consists of a number of elements each one of which is a couple of an active electromagnetic dipole, made from thin metallic wire and covered with cylindrically shaped dielectric material, and a parasitic electromagnetic dipole, made from thin metallic wire as well, which is adherent to the surface of the dielectric material that covers the active dipole. Parasitic dipoles must have shorter length than that of the active ones. Array elements are ordered in a collinear arrangement, which means that the direction of active and parasitic dipoles coincides with that of the arrangement of the elements, which is called direction or axis of the array. All active dipoles have the same length, except for the two far-out active dipoles that can be constructed with a little longer length than the other active ones. All parasitic dipoles have the same length as well, except for the two far-out parasitic dipoles that can be constructed with a little longer length than the other parasitic ones. The distances between adjacent active dipoles are equal to each other and equal to the corresponding distances between parasitic dipoles. The dielectric material that covers the active dipoles can be used in two different ways. The first way is the use of separate dielectric cylinders, each one of which has a length equal to the length of the corresponding covered active dipole, which means that the number of dielectric cylinders used must be equal to that of the active dipoles. The second way is the use of a united dielectric cylinder with the appropriate length to cover all the active dipoles at once. The array is situated in space so that its axis coincides with the desirable polarization direction of radiated electrical field. Behind the array in a defined distance there is a reflector consisted of a metallic mast, situated in direction parallel to array axis, and two orthogonal metallic surfaces on both sides of the mast, having the same length as the mast, defined width and being tangent to their lengthwise side on the mast surface. The two metallic surfaces form a specific angle, on the bisector of which the array is located, and can be implemented in two ways, either by metallic wire grid or by thin metallic poles of the same length and in direction parallel to that of the mast, so that the distance between the mast surface and the most far-off pole represents the metallic surface width. The feeding of the active dipoles can be either uniform or non-uniform and is applied in the middle point of these dipoles.

According to the above description, the distance between each active and opposite parasitic dipole, the lengths and diameters of the dipoles, their distance to the mast, the distance between active or between parasitic dipoles along the array axis, the length and diameter of the mast and finally the length and width of the two orthogonal metallic surfaces on the both sides of the mast are determinative magnitudes in order to obtain resonance condition in two different frequencies, the same specific half power angular beam-width and low secondary lobe level in these two frequencies at once and finally to maximize power gain in both two frequencies as well as far as much maximization is permitted by the number of array elements, the resonance, the specific half power beam-width and the low secondary lobe level that have been achieved.

According to the above description, the reason, why the far-out active and parasitic dipoles of the array must have a little greater length than the other active and parasitic ones, is that coupling is weak enough at the far-out dipoles due to their position, so their resonance is weaker than that of the other dipoles. Therefore, a short augmentation in the length of the far-out dipoles is desirable to enhance their resonance.

According to the above description, the reasons, why active dipoles must be covered by dielectric material, are: (a) active dipoles can be in resonance having shorter physical length, thus the distance between them along the array axis can be decreased, and since this distance is also the distance between parasitic dipoles along array axis, the level of some side secondary lobes of radiation pattern, that usually appear strong in one of the two frequencies with the higher value, diminishes effectively, (b) the use of dielectric material helps the frequency widening of resonance in both two frequencies, meaning that the width of the two frequency bands, in which array elements are asked to resonate, augments so that the required bandwidth will be obtained.

According to the above description, non-uniform feeding of active dipoles is generally used to diminish side secondary lobe level of radiation pattern in both two frequencies. Thus, if feeding amplitudes agree with Chebyshev type, the side lobe level can decrease under 20dB (deciBel) relatively to the main radiation lobe, which is a very good value according to the demands the array has to satisfy. No matter to if feeding amplitudes are uniform or non-uniform, a phase difference can be applied in active dipoles feeding, resulting in the main radiation lobe tilting relatively to the perpendicular to array axis direction at a certain angle. If there is no phase difference in feeding, the main lobe direction is perpendicular to array axis and is guided from the reflector mast towards the dipoles.

The advantages of the invention are related to the satisfaction of every demand defined to accomplish a wireless transmission-reception in two frequency bands at once. All the array elements give excellent resonance in both two frequencies and certainly with wide frequency band that is probably demanded in every application. This signifies that there is no power loss due to the reflection effect along the transmission line that feeds active dipoles. The half power angular beam-width of the radiation pattern has the same value in both two frequencies, meaning that radiation pattern covers exactly the same land surface in both two frequencies. Power gain has the most possible highest value and the level of every secondary lobe lies in low values relative to the main lobe in both two frequencies. As the array elements consist of metallic wire dipoles, high total power can be emitted. However, it is of the greatest importance the fact that the antenna array can combine all the above advantages at once, something that cannot easily be achieved by other antenna types in the same technical area with the one of the invention.

The present invention can be fully understood from the following description regarding the attached figures, wherein figure 1 and 2 show two perspective views of the whole structure respectively from two different optical angles, while figure 3 shows a part of the structure in enlargement so composition details of each array element will be visible.

For the reader’s facilitation, similar numbers and reference symbols are used for the definition of structure parts, distances and dimensions pictured in the three figures.

Figures 1 and 2 depict the whole structure from two different optical angles. The antenna array consists of 7 elements, without prohibiting array synthesis by any number of elements. At the back of the array, the reflector is visible, which consists of a metallic mast (1) of length H and diameter D, while on its left and right sides there are two orthogonal metallic surfaces (2) of same length H as that of the mast and width L. Each metallic surface touches its lengthwise side, of length H, on the mast surface. Each metallic surface is implemented either with metallic wire grid or with thin metallic poles, of length H, parallel to the mast, so that the distance between the mast surface and the most far-off pole will be equal to the width L of the metallic surface. The angular width between the two metallic surfaces is equal to 120 degrees, without prohibiting different values for this width.

Using armrests (3) array elements are situated in front of the reflector and on the bisector of the angular width formed by the two reflector metallic surfaces. The armrests can be made either from metal or from dielectric material. However, it is suggested that they be made of dielectric material, as long as the element weight is small, because if they are metallic, conductivity currents will be generating along them, resulting in their little radiation, which may slightly deteriorate the emitted radiation characteristics of the structure.

Each array element consists of an active dipole of length Z_E surrounded by dielectric material (4), of relative dielectric constant ε_r, on whose surface a parasitic dipole (5) of length Z_Π is adherent. As it can be seen in all figures, dielectric material has cylindrical shape of a length Z_E same as that of active dipole. Alternatively, instead of using a separate dielectric cylinder for each active dipole, a united cylinder can be used having the appropriate length so as to cover all active dipoles. Elements are equidistant to their neighbor ones at a distance S along the array axis. This distance coincides with the distance between the active as much as with the distance between the parasitic dipoles along the array axis. It must be pointed that this distance is measured from the middle point of an element to the middle point of the next one. Additionally, all of the elements are equidistant to the reflector mast. The distance between the surface of the dielectric material, which covers active dipoles, and the surface of the reflector mast is R_E.

In figure 3, a part of the structure with an array element in enlargement is shown so that the composition details of each array element will be perceivable. Here one can see the active dipole (6), of length Z_E and diameter d_E, surrounded by the dielectric cylinder (4), which has the length Z_E same as that of active dipole, diameter d_Δ and relative dielectric constant ε_r. The parasitic dipole (5), of length Z_Π and diameter d_Π, is adjusted to the cylinder surface. The element is located in front of the reflector with the help of a respective armrest (3), so that the distance between the mast surface (1) and the dielectric cylinder surface (4) is R_E.

Two following examples are given, in order to clarify the advantages of the invention. The 7 elements array, that has been described in the figures, is used, in both two examples, for a mobile telephony base station, which operates in two frequency bands, the band of 900MHz and the band of 1800MHz, of which the first one rates from 880MHz to 960MHz with bandwidth 80MHz and the second one from 1710MHz to 1880MHz with bandwidth 170MHz. Of course, the whole structure must be located in space with the mast in vertical direction, so that vertical polarization of radiation electric field, demanded for the case of mobile telephony, will be succeeded.

Example 1

Good resonance for each of the 7 elements is required in both two frequencies with the required bandwidth in each frequency, every secondary lobe level at least 20dB (deciBel) under the main lobe level and the half power angular beam-width of the horizontal radiation pattern equal to 120 degrees. Of course, the antenna array has to satisfy the above demands in both two operation frequency bands of mobile telephony base station.

The above demands are succeeded by using a mast (1) of diameter D=1 inch and H=114,4 centimeters in length, metallic reflector surfaces (2) of the same length and L=5,5 centimeters in width, active dipoles (6) of diameter d_E=2,7 millimeters and Z_E=11,5 centimeters in length, except for the two far-out ones of Z_E=11,8 centimeters in length, parasitic dipoles (5) of diameter d_Π=2,7 millimeters and Z_Π=7 centimeters in length, dielectric cylinders (4) of relative dielectric constant ε_r=2,5 and diameter d_Δ=9,9 millimeters, while the length of each cylinder is equal to the length Z_E of the respective covered active dipole. The distance from the mast surface to each dielectric cylinder surface is R_E=5 centimeters and the distance between neighbor elements on vertical direction is S=12,7 centimeters. Additionally, the construction of every metallic part of the structure, that is the mast, the metallic reflector surfaces, the active and parasitic dipoles, is implemented by using copper, while the armrests (3) are made from dielectric material.

Applying a non-uniform feeding of Chebyshev type without phase difference to active dipoles, we get the results given bellow: The half power angular beam-width on the horizontal plane is 120 degrees in both two frequencies. Every secondary lobe has a level under 20dB in 900MHz and under 20,6dB in 1800MHz relatively to the main lobe. The power gain has a value of 11,7dB in 900MHz and 14,7dB in 1800MHz. All array elements have a resonance bandwidth of 104MHz around the frequency of 900MHz, specifically from 856MHz to 960MHz, while around the frequency of 1800MHz the resonance bandwidth is 183MHz, specifically from 1697MHz to 1880MHz. In order to show how good resonance we get from each of the 7 elements in both two frequencies, the return loss will be given separately for each element. Starting from the bottom of the array and moving upwards, in 900MHz the return loss is equal to -26,3dB for the first and seventh element, -23,4dB for the second and sixth element, -27,6dB for the third and fifth element and -27,9dB for the forth element, while in 1800MHz the return loss is equal to -50,7dB for the first and seventh element, -26dB for the second and sixth element, -29,4dB for the third and fifth element and -30,9dB for the forth element.

All demands in the given application of the example are satisfied more than asked, just like the resonance bandwidth in both two frequencies. Of course, it must be pointed out that the set of geometric dimension values of the structure mentioned above is not the only one that satisfies the demands we ask from the structure. There are, namely, additional sets of values for structure dimensions that can give similarly good results.

Example 2

Good resonance for each of the 7 elements is required in both two frequencies with the required bandwidth in each frequency, every secondary lobe level at least 20dB (deciBel) under the main lobe level and the half power angular beam-width of horizontal radiation pattern equal to 60 degrees. Of course, the antenna array has to satisfy the above demands in both two operation frequency bands of mobile telephony base station.

The above demands are succeeded by using a mast (1) of diameter D=1 inch and H=114,4 centimeters in length, metallic reflector surfaces (2) of the same length and L=21,8 centimeters in width, active dipoles (6) of diameter d_E=2,7 millimeters and Z_E=11,4 centimeters in length, except for the two far-out ones of Z_E=11,9 centimeters in length, parasitic dipoles (5) of diameter d_Π=2,7 millimeters and Z_Π=7 centimeters in length, dielectric cylinders (4) of relative dielectric constant ε_r=2,55 and diameter d_Δ=9,7 millimeters, while the length of each cylinder is equal to the length Z_E of the respective covered active dipole. The distance from the mast surface to each dielectric cylinder surface is R_E=4,8 centimeters and the distance between neighbor elements on vertical direction is S=13 centimeters. As in the previous example, the construction of every metallic part of the structure, that is the mast, the metallic reflector surfaces, the active and parasitic dipoles, is implemented by using copper, while the armrests (3) are made from by dielectric material.

Applying a non-uniform feeding of Chebyshev type without phase difference to active dipoles, we get the results given bellow: The half power angular beam-width on the horizontal plane is 60 degrees in both two frequencies. Every secondary lobe has a level under 20,2dB in 900MHz and under 20,6dB in 1800MHz relative to the main lobe. The power gain has a value of 14,8dB in 900MHz and 17,6dB in 1800MHz. All array elements have a resonance bandwidth of 108MHz around the frequency of 900MHz, specifically from 856MHz to 964MHz, while around the frequency of 1800MHz the resonance bandwidth is 188MHz, specifically from 1695MHz to 1883MHz. In order to show how good resonance we get from each of the 7 elements in both two frequencies, the return loss will be given separately for each element. Starting from the bottom of the array and moving upwards, in 900MHz the return loss is equal to -27,1dB for the first and seventh element, -27,2dB for the second and sixth element, -27,3dB for the third and fifth element and -25,7dB for the forth element, while in 1800MHz the return loss is equal to -41,4dB for the first and seventh element, -24,6dB for the second and sixth element, -27,3dB for the third and fifth element and -28,8dB for the forth element.

Also in this example, all demands in the given application are satisfied more than asked, just like the resonance bandwidth in both two frequencies. Of course, it must be pointed out again that the set of geometric dimension values of the structure mentioned above is not the only one that satisfies the demands we ask from the structure. There are, namely, additional sets of values for structure dimensions that can give similarly good results.

In case we ask, besides the previous demands in both two examples, a main lobe tilt to the ground at a given angle, there are two ways to achieve that, either by mechanical inclination of the structure at the same angle relative to vertical direction, or by giving the appropriate phase difference on active dipoles feeding.

C L A I M S

1. The dual band dipole antenna array with corner reflector consists of a reflector, which is composed of a metallic mast (1) and two orthogonal metallic surfaces (2), of length as that of the mast, being tangent to their lengthwise side on the mast surface and shaping a certain angular width, and an antenna array in front of the reflector, in direction parallel to the mast (1), at a certain distance from it, on the bisector of the angular width the two orthogonal metallic surfaces (2) form, which consists of a set of equidistant elements, fixed to the mast (1) with the help of metallic or dielectric armrests (3), and is characterized by the fact that each array element consists of an active dipole (6) made of thin metallic wire and covered along its whole length with cylindrically shaped dielectric material (4), and also of a parasitic dipole (5) adherent to the dielectric material surface, made of thin metallic wire and having shorter length than the active dipole (6), so that each array element will resonate in two frequencies at once with a wide bandwidth in each of these frequencies.

2. According to claim 1, the dual band dipole antenna array with corner reflector is characterized by the fact that active (6) and parasitic dipoles (5) have a direction that coincides with that of the array axis.

3. According to claim 1, the dual band dipole antenna array with corner reflector is characterized by the fact that active dipoles (6) of the array have the same length except for the two far-out active dipoles, which can be constructed with little longer length than the other ones, so that better coupling and consequently better resonance will be achieved in the far-out active dipoles.

4. According to claim 1, the dual band dipole antenna array with corner reflector is characterized by the fact that parasitic dipoles (5) of the array have the same length except for the two far-out parasitic dipoles, which can be constructed with little greater length than the other ones, in order that better coupling and consequently better resonance will be achieved in the far-out parasitic dipoles.

5. According to claim 1, the dual band dipole antenna array with corner reflector is characterized by the fact that dielectric material (4) that covers active dipole (6) can have either the form of separate cylinders, each one of which has a length equal to the length of the corresponding covered active dipole, or the form of a united dielectric cylinder with the appropriate length to cover all the active dipoles at once.

6. According to claims 1 to 5, the dual band dipole antenna array with corner reflector is characterized by the fact that the distance between each active (6) and opposite parasitic dipole (5), the lengths and diameters of the dipoles, their distance from the mast, the distance between active or between parasitic dipoles along the array axis, the length and diameter of the reflector

mast (1) and finally the length and width of the two orthogonal metallic surfaces (2) on both sides of the mast must have specific values in order to succeed resonance condition in two different frequencies, the same specific half power angular beam-width and low secondary lobe level in these two frequencies at once and finally to maximize power gain in both these two frequencies as well, as far as much maximization is permitted by the number of array elements, the resonance, the specific half power beam-width and the low secondary lobe level that have been achieved.

7. According to claims 1, 2 and 3, the dual band dipole antenna array with corner reflector is characterized by the fact that feeding of active dipoles (6) can be either uniform or non-uniform, with or without phase difference and is applied on the middle point of these dipoles.

A B S T R A C T

Dual band dipole antenna array with corner reflector

The dual band dipole antenna array with corner reflector belongs to the category of reflector antenna arrays that are used in wireless telecommunication base stations, like the case of mobile telephony, and gives good and wide resonance in two frequency bands simultaneously, preserving in both two bands the same half power angular beam-width, the low secondary lobe level and the most possible maximum power gain, that are demanded according to any case.

The dual band dipole antenna array with corner reflector consists of a mast (1) and two surfaces (2), that together compose the reflector, and an antenna array in front of the mast, situated on an axis parallel to the mast direction and composed of equidistant elements, which are orientated to array axis and fixed to the mast with the help of armrests (3). Each element consists of an active dipole (6) with dielectric cover (4), on whose surface a parasitic dipole (5) is adherent. The far-out active dipoles, in order to give better resonance, can have little larger length than the other active ones, which can be of the same length, and this construction technique is applied on parasitic dipoles as well.

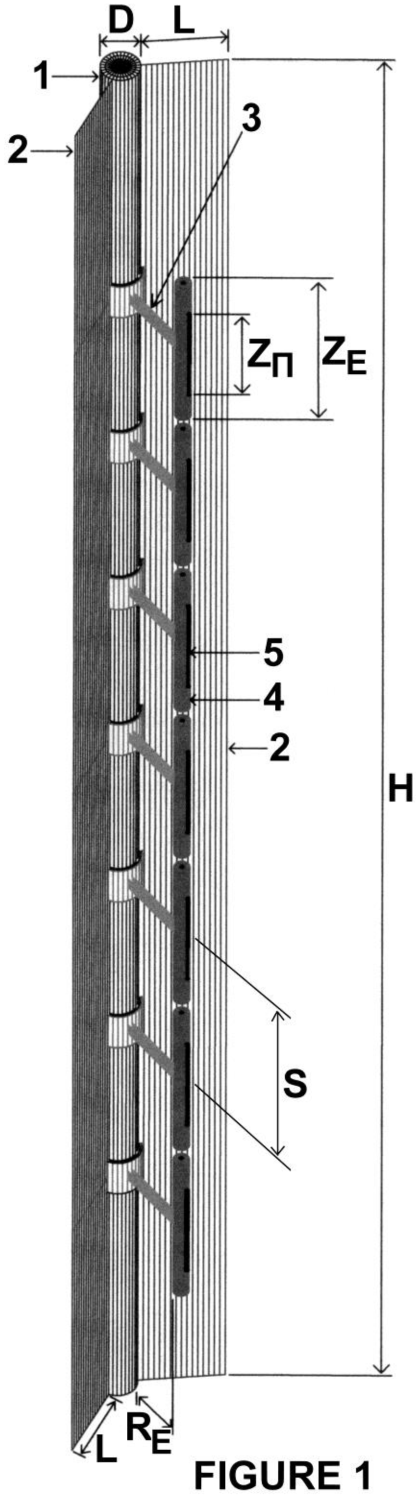

FIGURE 1

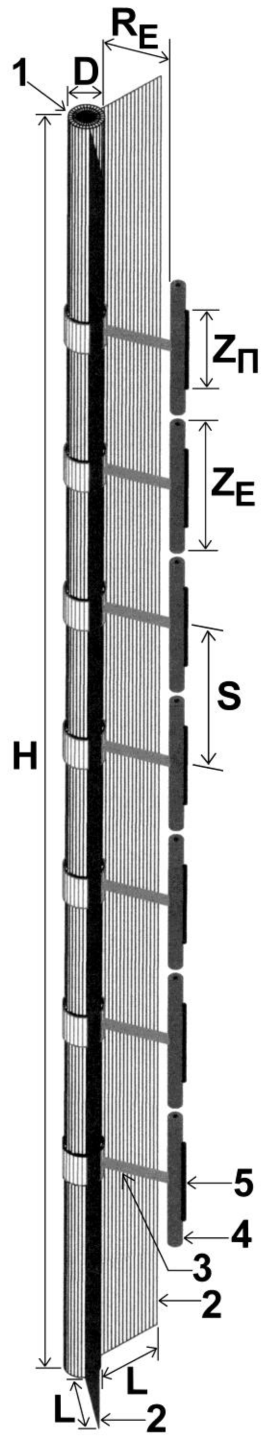

FIGURE 2

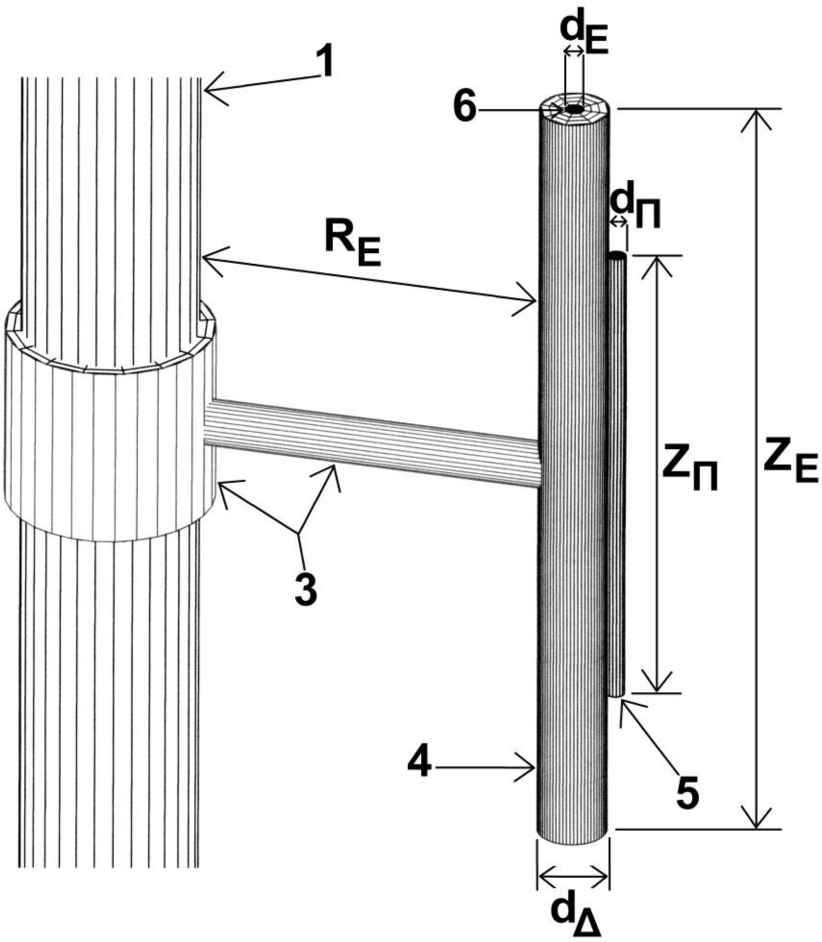

FIGURE 3